MANITOBA GUIDELINES

AGRICULTURAL IRRIGATION USING TREATED MUNICIPAL WASTEWATER

Manitoba
Rural Development

The Manitoba
Water Services
Board

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FORWARD

This paper was completed by the Technical Advisory Committee for Roblin Wastewater Irrigation Monitoring Program. The Committee consisted of representatives from several Provincial government departments, University of Manitoba, and the private sector.

Initial drafts of this report were prepared by the late F.F. Penkava who passed away February 1987. Dr. Penkava was Professor in the Agricultural Engineering Department, University of Manitoba where he held the position of Irrigation and Drainage Engineer.

1990

TABLE OF CONTENTS

Page

1.0 Introduction 5
- 1.1 Use of Wastewater Irrigation 5
- 1.2 Legal Requirements 5
- 1.3 Application of the Guidelines - Background 5
- 1.4 Irrigation Practice and Goals 6

2.0 Making Decisions - Determining Feasibility 6
- 2.1 Wastewater Quality 6
  - 2.1.1 Chemical Analysis 6
  - 2.1.2 Microbiological Analysis 6
- 2.2 Land Base 7
  - 2.2.1 Distance from Source 7
  - 2.2.2 Accessibility 7
  - 2.2.3 Topography 7
  - 2.2.4 Buffer Zones 7
- 2.3 Soils 8
  - 2.3.1 Physical and Chemical Properties 8
  - 2.3.2 Depth to Groundwater or Bedrock 8
- 2.4 Crops 8
- 2.5 System Selection 8
- 2.6 Agreements and Cost Sharing 9

3.0 System Design 9
- 3.1 Additional Investigations 9
- 3.2 Instructions for System Operation 9

4.0 Operating A Wastewater Irrigation System 9
- 4.1 Health 9
- 4.2 Monitoring the System 10
- 4.3 Access to the Irrigation Site 10

5.0 Caution - Guideline Usage 10

Appendix I - Legislation Affecting Agricultural Irrigation Using Treated Municipal Wastewater 11

Appendix II - References 11

Appendix III - Glossary of Selected Terms 12

Appendix IV - Checklist - Initial Design and Monitoring 14

1.0 INTRODUCTION

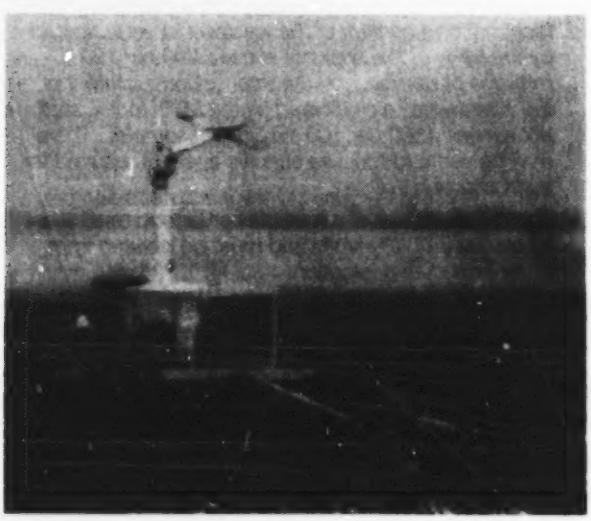
These guidelines provide basic information about the more important aspects of preparing, designing and operating agricultural irrigation systems using treated municipal wastewater or effluent.

1.1 USE OF WASTEWATER IRRIGATION

The primary goal of using municipal wastewater for irrigation purposes is a safe way to dispose of treated effluents onto agricultural lands. Under suitable conditions wastewater irrigation is less disruptive to the environment than discharging the wastewater into our rivers, lakes or streams.

Secondly, a properly conceived, designed and operated irrigation system using treated municipal wastewater may also provide an inexpensive source of supplemental moisture and some nutrients for crop production.

To meet the goals of safe disposal and crop nutrition, a wastewater irrigation system must be able to dispose of the wastewater safely, fully, and in the time period described on the licence; while satisfying all the principles of sound irrigation practice. When properly designed, installed and operated, a wastewater irrigation system should also preserve the productivity of the land; the quality of the produce; and the health of the operators, their families, and the general public.



1.2 LEGAL REQUIREMENTS

Wastewater irrigation must comply with existing legislation, which includes, but may not be limited to, the following:

1. Any use of wastewater is authorized by licence under The Environment Act. *(Department of the Environment).*
2. Wastewater irrigation systems are to be designed and operated in compliance with The Workplace Safety and Health Act. *(Department of Labour).*
3. Where permanent or temporary pipelines, canals, pumping stations or any other parts of the proposed irrigation system need to cross, or in any other way intrude on public or private property, the same legal requirements such as approvals, easements, etc. apply as in the case of any irrigation system.
4. According to the legal opinion of Crown Council, there is no requirement under The Water Rights Act to license the use of wastewater from a sewage lagoon.

NOTE: A listing of legislation applicable to wastewater irrigation and a contact from each Department is attached as Appendix I.

1.3 APPLICATION OF THE GUIDELINES - BACKGROUND

Municipal wastewater irrigation is relatively new technology so the practices governing it are in the informative stages.

These guidelines were primarily developed from data obtained from monitoring an experimental municipal wastewater irrigation system south of the Town of Roblin. The system was installed in 1981 and monitored in the summers of 1982, 1983 and 1984. The system has continued to operate in the growing seasons since then. Information about wastewater irrigation systems in Alberta and Saskatchewan has also been used in preparing these guidelines.

It has to be realized that the experience and information from Roblin, and from Saskatchewan and Alberta was gathered over a relatively short time period. Also, many aspects of irrigation using wastewater may be site-specific.

Caution and good judgement must be used when applying the recommendations contained in these Guidelines.

Excellent technical resource manuals include Environment Canada's "Manual for Land Application of Treated Municipal Wastewater and Sludge" and the Environmental Protection Agency's *(EPA)* "Process Design Manual: Land Treatment of Municipal Wastewater". *(See Appendix II).*

1.4 IRRIGATION PRACTICE AND GOALS

Wastewater irrigation should be based on the consumptive use of the crop – that is, crop water needs plus an allowance for leaching *(a water requirement in excess of crop needs which moves the minerals and excess water below the root zone).* The design and operation of the system(s) should be governed further by soil intake and storage capabilities, and by crop characteristics.

2.0 MAKING DECISIONS - DETERMINING FEASIBILITY

There are several factors to consider in the preparation and design of a wastewater irrigation scheme as outlined in this section.

2.1 WASTEWATER QUALITY

Both the chemical and biological qualities of the wastewater must be thoroughly tested early in the decision-making stage. Since the quality of the wastewater may change during the irrigation season, it is strongly recommended that the decision as to whether the wastewater is suitable for irrigation be made on the basis of at least three water samplings: at the beginning, the peak and before the end of the irrigation season. If data for more than one season are available, they should be considered.

2.1.1 Chemical Analysis

To evaluate chemical suitability, the wastewater should be tested for all parameters listed in "Irrigation Water Quality Standards", a pamphlet prepared by Manitoba Agriculture and available without charge. *(See Reference 3, Appendix II).*

If complete analysis is not feasible, the test must include at the very least an analysis of pH, the Sodium Adsorption Ratio *(SAR)*, electrical conductivity *(EC)*, boron, manganese, nitrate and nitrite nitrogen, chloride, phosphorus, sulphates, and potassium.

If there is an industry which may be discharging other toxic materials or elements into the municipal sewage system, these materials or elements must be identified at this stage and included in the chemical analysis of the wastewater.

To determine the suitability of the wastewater for irrigation, the limits given in the "Irrigation Water Quality Standards" pamphlet should be used. In situations similar to those at Roblin, and for the irrigation of alfalfa *(the crop most commonly used for wastewater irrigation)*, wastewater with manganese content of up to 0.25 milligram/litre and with short term *(usually spring sampling)* readings up to 1.00 milligrams per litre and chloride up to 250 milligram/litre and 350 milligram/litre *(spring sampling)* may be considered as acceptable.

Chemical tests should be carried out by the W.M. Ward Technical Services Laboratory *(Manitoba Environment)*, 745 Logan Avenue, Winnipeg, Manitoba, R3E 3L5. Containers for the samples of the wastewater and instructions on proper sampling procedures and on handling the wastewater samples are obtained from the Ward Laboratory.

2.1.2 Microbiological Analysis

Generally, the range of the tests and the acceptance limits are the same as those for the suitability of treated wastewater for direct discharge into streams *(e.g. the fecal coliform content of the wastewater, as indicated by the MPN Index, shall not exceed 200 per 100 millilitres of sample; and the total coliform content of the wastewater, as indicated by the MPN Index, shall not exceed 1500 per 100 millilitres of sample).* There may be some further site specific analysis required for each irrigation system.

The discharge cell of a multiple cell lagoon must meet wastewater quality limits and must be isolated from other cells during irrigation.

Analysis should be done at the Cadham Provincial Laboratory *(Manitoba Health Services Commission)* 750 William Avenue, Winnipeg, Manitoba, R3C 3Y1. Sampling bottles and instructions are also obtained from Cadham Laboratory.

2.2 LAND BASE

Negotiations to secure an appropriate amount of land base must be made early in the preparation stage. Since overirrigation must be avoided from health and for other considerations such as crop tolerance to flooded conditions, site specific parameters *(described in the forthcoming paragraphs, Section 2.2)* must form part of the overall land base so that the wastewater can be disposed of in relatively wet years without compromising the principles of good irrigation.

Another factor to consider is that irrigation needs will vary from year to year according to local weather conditions which may, in turn, change the area of land under irrigation.

Yet another important factor is the growth of the municipality and the resulting increase in wastewater available for irrigation purposes. This, in turn, requires that adequate land base be secured for future growth expectations.

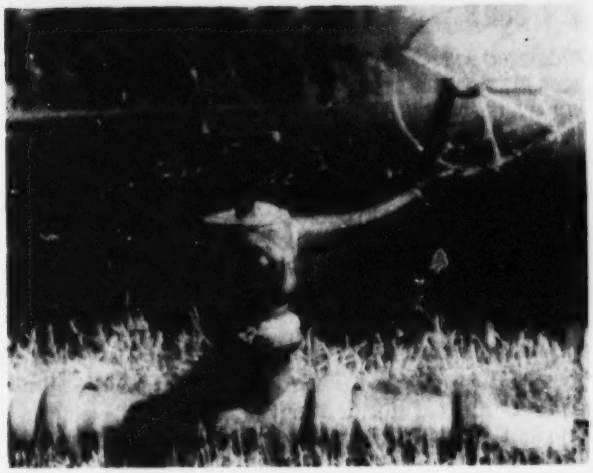
The minimum, average and maximum areas required for the safe disposal of the wastewater through irrigation is calculated at different stages of the anticipated economic lifetime of the wastewater processing system. This is done by dividing the volume of wastewater to be disposed of by the gross irrigation water requirement *(including the leaching requirement, if applicable)* for the crop or crops in question in medium dry, average and medium wet years. The gross irrigation water requirement should be calculated according to accepted irrigation principles.

2.2.1 Distance from the Source

Proximity of the wastewater lagoon relative to the irrigation site will have significant impact on the project's feasibility. As the distance of the irrigation site increases from the lagoon the longer the pipeline *(or open conduits if the wastewater meets discharge requirements)* and, in turn, construction, maintenance and operation costs will increase accordingly.

2.2.2 Accessibility

Ready access of the pipeline is equally important. Factors such as highway, railway or road crossings, high or low ground, streams and property belonging to a third party may involve special costly structures, additional contractual arrangements, and legal requirements.



2.2.3 Topography

The surface topography is important not only in the system design stage but also in the context of surface hydrology. Sites with rapid and extensive run-off, especially with direct access to streams and other open water bodies, must be avoided. Sites from which runoff may enter areas and facilities that are sensitive because of possible adverse impacts on public health *(such as wells, playgrounds, campgrounds, etc.)* are unacceptable.

Sites with minimum runoff are especially desirable if irrigation methods using overland flow of wastewater *(irrigation from gated pipes, border irrigation, and similar methods)* are to be used.

2.2.4 Buffer Zones

Safe distances must be provided between the irrigated area and surrounding areas and facilities that are sensitive because of health reasons and where wastewater irrigation may cause annoyance.

Areas considered high risk include recreational areas, playgrounds, schools, public parks, residential, Provincial Roads and Trunk Highways, and major municipal roads. The minimum buffer zone requirement is 200 metres.

Low risk areas include low-use municipal roads and private land belonging to a third party and where land use practices are not categorized as high risk. A buffer zone of 100 metres is suggested for low risk areas, however, site specific circumstances may permit smaller buffer zones.

2.3 SOILS

A detailed soil survey must be conducted by a qualified soils Agrologist at the decision stage of the project. The survey must contain a basic network of deep probes and a denser network of additional probes. The density of sampling will reflect the complexity of the particular situation. The deep probes should be drilled a depth of at least 5.0 metres and to bedrock *(if closer to the surface than 5.0 metres)*. Additional probes should be at least 1.5 metres deep or reach bedrock, if closer.

The holes should be described in terms of geological material, soil type, soil texture and structure, depth of groundwater table, presence of stones, etc.

Soil samples for laboratory analysis should be taken from each horizon and analyzed for soluble salts, pH, electrical conductivity, and SAR.

2.3.1 Physical and Chemical Properties

A wide range of soils are suitable for wastewater irrigation if proper irrigation methods are selected and the system properly designed and operated. Preference however, should be given to soils with good water intake rates and good water holding capacity. Medium-textured soils such as sandy loams and loams with well developed and stable soil structures are preferable, while heavy clays and coarse sands should be avoided because of design complications and increased operating costs.

Saline soils should not be irrigated with wastewater except in areas where very good leaching conditions either exist, or can be provided through artificial drainage or in areas where leaching will have no significant adverse impact on groundwater or where surface runoff from irrigated saline soils do not adversely affect the recipients of the surface drainage waters.

2.3.2 Depth to Groundwater or Bedrock

A groundwater appraisal for the irrigation site should be conducted by a hydro-geologist from the Water Resources Branch of Manitoba Natural Resources. Further site-specific evaluation may be required.

The irrigation sites should have at least 1.5 metres of non-water-logged root zone that is available for crop growth. Where the depth of the soil to bedrock is less than 1.5 metres, wastewater irrigation should not be used. The same 1.5 metre depth applies to aquifers not used for water supply, unless the natural *(permanent or temporary) groundwater levels can be lowered (more than 1.5 metres depth)* and maintained by artificial drainage.

On land overlying aquifers used for water supply, the depth to the groundwater table should be at least 3.0 metres. Such land overlying aquifers regardless of depth to the water table, the soil structure and water quality should be investigated to prevent groundwater contamination *(ie. if electrical conductivity and sodium adsorption ratio indicates that leaching is required, this site is not permitted for irrigation).*

2.4 CROPS

CROPS *(EG. VEGETABLES OR FRUIT)* WHICH MAY BE EATEN RAW OR UNPROCESSED BY HUMANS MUST NOT BE IRRIGATED WITH WASTEWATER. This includes corn as bacteria can reproduce within the husk.

Crops recommended for wastewater irrigation are alfalfa *(the most commonly used crop)* and other forage crops. Tree nurseries and sod farms may also benefit from wastewater irrigation. Harvesting or grazing must not begin sooner than seven days following the last wastewater irrigation UNLESS this irrigation was followed by at least 10.0 millimetres of rain OR irrigation with standard quality irrigation water OR there has been AT LEAST a total of 24 hours of bright sunshine.

2.5 SYSTEM SELECTION

Most sprinkler irrigation systems are suitable for wastewater irrigation. Automated systems with low human contact with the wastewater, the equipment and the irrigated crop, such as centre-pivot or lateral-move systems are highly preferable. Systems involving higher labour/wastewater contact, for instance, side-roll systems and especially hand-move systems are least suitable. Such equipment options as low pressure versus high pressure systems should be considered because water droplet size affects spray pattern and wind drift.

Big guns, either stationary or travellers, will require additional buffer zones. Drip and trickle irrigation systems are not recommended for wastewater irrigation because of the high probability of malfunctions.

Overland flow irrigation systems may be suitable in some circumstances especially as back-up extensions of the basic systems and where the micro-topography of the irrigated area permits uniform water distribution.

2.6 AGREEMENTS AND COST SHARING

Early in the decision making process, the obligations of the wastewater producer *(the town or municipality)* and the user *(the farmer)* must be clarified and contractually secured. This will include the agreement to use the wastewater *(providing the water quality is satisfactory)*; cost sharing arrangements for design, construction, and maintenance; the location of system components; access to the system; monitoring and sampling responsibilities; emergency provisions, profit sharing arrangements *(if any)*; and other factors affecting the preparation, construction, maintenance, and management of the system.

In a similar way the relations with and obligations towards third parties, such as those related to Accessibility in Section 2.2 must be clarified and contractually secured.

3.0 SYSTEM DESIGN

The designer of the system or of any of the system's parts or components should comply with the guidelines of Sections 1 and 2 as well as accommodate any design factors resulting from agreements and contracts under Section 2.6 of the Guidelines.

As well, the wastewater irrigation system's design should be technically sound and represent the current "state of the art" technology of the disciplines involved as well as provide the flexibility needed to meet fluctuating water requirements depending on weather conditions/ wastewater supply as outlined in Section 2.2.

3.1 ADDITIONAL INVESTIGATIONS

The system designer should interpret and use the information contained in all the preliminary reports as well as conduct other additional investigation and gather additional data as needed.

The producer of the wastewater *(the town or municipality)* and the involved property owner are expected to assist the designer and make information in their possession available to the designer.

3.2 INSTRUCTIONS FOR SYSTEM OPERATION

The design should incorporate detailed operating instructions which will include:

- How to operate the equipment;
- Instructions to monitor the performance of the system;
- Allowable maximum application amounts *(quantities)* and rates;
- Monitoring requirements for;
  - Wastewater quality
  - Soil fertility
  - Groundwater levels and quality, if applicable
- Emergency measures; and
- Other instructions specific to each wastewater irrigation installation for the safe operation of the system.

4.0 OPERATING A WASTEWATER IRRIGATION SYSTEM

There are several other factors for the operation of a wastewater irrigation system as discussed in the forthcoming sections.

4.1 HEALTH

Because the potential does exist for bacterial infections from wastewater, property owners and wastewater treatment facility employees are advised to contact the

Health office *(Medical Officer of Health)* in the planning stages to discuss the specific and general health issues connected with wastewater irrigation. Generally, immunization is not required although routine immunizations should be up to date *(diptheria, tetanus, polio).*

It is recommended that operators, their families, employees and anyone else involved with operating the system have thorough medical check-ups prior to the start-up of the system. These people are also encouraged to see their doctors should health problems arise during the irrigation season and should report any illness to the local public health office.

Should a widespread outbreak of intestinal infection occur within the community, the owner of the wastewater treatment facility *(town or municipality)* should inform the Department of Environment and the Department of Health and all wastewater irrigation shall be discontinued. The irrigation system shall be restarted only with the authorization of the Medical Officer of Health.

Employees working with the system should be restricted to essential tasks only and should wear adequate protective clothing. Personal hygiene is important and regular hand-washing and other good hygienic methods should be practiced to decrease the likelihood of spread of germs from hand or skin to the mouth.

The irrigation "spray" shall not infringe into the buffer zone at any time, even in high winds and the operator assumes responsibility that the irrigation system cease operation under these circumstances.

4.2 MONITORING THE SYSTEM

The importance of continuous and thorough monitoring practices cannot be over emphasized.

Soil conditions should be tested every year by a qualified soils agrologist. Sampling density and depth shall be specified by the agrologist. Soil analysis shall be the same as that specified in Section 2.3. Results of all soil tests shall be recorded and kept.

Wastewater quality from the discharge cell should be tested before the opening of the irrigation season and at least once during the growing season. If only one additional sampling is done, it should be in July or August. Sampling procedures, chemical and microbiological parameters and evaluation shall be similar to the method outlined in Section 2.1.

Monitoring water quality in water wells in or adjacent to an irrigation area *(if required in the Environment license)* should be analyzed for the same parameters as the wastewater to determine both chemical and microbiological content *(see Section 2.1)*. In addition, potable well water adjacent to an irrigation area should also be analyzed for coliform count and compared to current guidelines for Canadian Drinking Water Quality.

4.3 ACCESS TO THE IRRIGATION SITE

Prominently displayed signs stating "SEWAGE EFFLUENT IRRIGATION - KEEP OUT" with a symbol incorporated to reinforce the wording shall be posted around the irrigation area. The sign shall be bilingual.

5.0 CAUTION - GUIDELINE USAGE

Because technical knowledge and practical experience with irrigation systems using municipal wastewater is still developing, these Guidelines must be used, as stated in Section 1.3, with caution and with good judgement.

As the need arises, these Guidelines will be updated as the technology and experience develop.

APPENDIX I

LEGISLATION AFFECTING AGRICULTURAL IRRIGATION USING TREATED MUNICIPAL WASTEWATER

The Municipal Act	Manitoba Rural Development Municipal Advisory and Financial Services 600 - 800 Portage Avenue Winnipeg, Manitoba R3G 0N4 Ph. 945-2194
The Manitoba Water Services Board Act	Manitoba Water Services Board Box 1059 2022 Currie Boulevard Brandon, Manitoba R7A 6A3 Ph. 726-6076
The Environment Act	Manitoba Environment Environmental Control Programs 139 Tuxedo Boulevard Winnipeg, Manitoba R3N 0H6 Ph. 945-7071
The Workplace Safety and Health Act	Manitoba Labour Workplace Safety and Health Division 10th Floor, 330 St. Mary Avenue Winnipeg, Manitoba R3C 3Z5 Ph. 945-3446
The Water Rights Act	Manitoba Natural Resources Water Rights Engineer 1567-1577 Dublin Avenue Winnipeg, Manitoba R3E 3J4 Ph. 945-6699
The Public Health Act	Manitoba Health Environmental Health Public Health Engineer 2nd Floor, 800 Portage Avenue Winnipeg, Manitoba R3G 0N4 Ph. 945-7857

MUNICIPALITIES AND PROPERTY OWNERS CONSIDERING INSTALLING IRRIGATION SYSTEMS MUST ENSURE THAT ALL LEGISLATION IS COMPLIED WITH. THE ABOVE LISTS THE MAJOR ACTS. HOWEVER, IN SOME INSTANCES, OTHER LEGISLATION MAY APPLY. PLEASE CONSULT WITH THE MANITOBA WATER SERVICES BOARD AT THE ABOVE ADDRESS.

APPENDIX II

REFERENCES

1. Environment Canada, 1984. Manual for Land Application of Treated Municipal Wastewater and Sludge. Prepared by Technical Working Committee. Manual EPS 6-EP-84-1. Available from: Environment Protection Service, Environment Canada, Ottawa, Ontario, Canada K1A 1C8.
2. U.S. Environmental Protection Agency, 1981. Process Design Manual for Land Treatment of Municipal Wastewater. Manual EOA 625/1-81-013. Available from: U.S. Environmental Protection Agency, Center for Environmental Research Information, Cincinnati, Ohio, USA 45268.
3. Klassen, G., 1983. Irrigation Water Quality Standards. Available from: Manitoba Agriculture, Room 915 Norquay Building, 401 York Avenue, Winnipeg, Manitoba R3C 0P8.
4. Health and Welfare Canada, 1987. Guidelines for Canadian Drinking Water Quality.

APPENDIX ■

GLOSSARY OF SELECTED TERMS

Aquifer - a permeable *(permits movement of water)* formation in which groundwater moves or is stored.

Buffer Zones - a designated area of land that separates the irrigated area from protected property.

Chemical Parameters:

a. **Boron** - is an essential element for plant growth but is needed in relatively small amounts. A Boron toxicity problem has been associated in irrigation water. Toxic levels for Boron are indicated in Irrigation Water Quality Standards - 1983.

b. **Manganese, Chloride, Nitrate Nitrogen (nitrogen portion of the nitrate ion), Phosphorus, Sulphate, Potassium** - are constituents in wastewater that are measured and then each is compared to irrigation water quality standards respectively. In general, as the level of each constituent increases, the potential exist to effect the tolerance of the crop. Irrigation Water Quality Standards - 1983 lists the limits for these parameters.

Easements - legal permission to install equipment *(eg. pipe(s) below ground)* across private property. Easements are to be registered on the property title.

Effluent - another name for "wastewater".

Electrical Conductivity (EC) - a measure of the electrical movement through water or a soil sample and is used to estimate salinity. The higher the conductivity the more saline in the water. Crop tolerance levels for various conductivities are indicated in Irrigation Water Quality Standards - 1983.

Groundwater - water accumulated beneath the ground surface in an aquifer.

Irrigation Systems:

High Pressure System - irrigation systems operating at pressures greater than 310 kPa *(45 psi)*.

Low Pressure System - irrigation systems operating at less than 310 kPa *(45 psi)* pressure.

Irrigation Water Requirements - the calculation of water required for irrigation which includes but is not limited to the following:

Water required = crop requirements *(or consumptive use)* plus leaching requirement minus stored water minus rainfall.

Leaching - the application of water in excess of crop needs which moves the minerals such as salts and excess water below the root zone.

Microbiological Terms:

a. **MPN Index** - MPN means Most Probable Number and is a technique used in a microbiological laboratory to estimate bacteria population, either total or fecal bacteria.

b. **Fecal Coliform** - human or animal waste bacteria as determined in a microbiological laboratory analysis.

Multiple Cell Lagoon - is a lagoon *(wastewater stabilization pond)* that has two or more cells or ponds in series for treatment of sewage.

Open Conduits - convey wastewater in an open channel or ditch.

pH - determines whether the soil or water is acid or basic. Different crops can tolerate different pH levels and generally the pH should be between 5 and 9.

Pipelines - convey wastewater in an enclosed pipe from the pumping station to the irrigation site.

Sodium Adsorption Ratio *(SAR)* - is the formula

$$\frac{0.043 * \text{Sodium}}{\sqrt{(0.025)\,\text{Calcium} + (0.04)\,\text{Magnesium}}}$$

The quality of irrigation water is determined by its salts and the principal salts include calcium, magnesium and sodium.

Knowing sodium, calcium and magnesium concentrations in mg/L,SAR can be calculated.

Knowing conductivity and SAR, and using a SAR - conductivity diagram, one can estimate the potential salinity hazard. Typically SAR greater than 15 should be avoided because of detrimental effect on soil structure and ultimate reduction in infiltration rates.

Sprinkler Irrigation Systems Includes:

a. **Centre Pivot System** - consists of a long pipe *(up to 800 m long)* supported on towers with sprinklers along its length. The system is pivoted at one end, and moves slowly during irrigation, sweeping a circular area.

b. **Lateral Move System** - similar to the centre pivot, except that neither end is fixed. The system is propelled sideways during irrigation, sweeping a rectangular area.

c. **Side Roll System** - consists of a long pipe *(up to 400 m)* which acts as the axle for a series of large, widely-spaced wheels. Sprinklers are located on the pipe between wheels. The system is stationary during sprinkling, and is propelled sideways between irrigation sets by means of a built-in mechanical mover.

d. **Hand Move System** - consists of a network of pipes lying on the ground, with sprinklers on risers. Pipe and sprinklers are moved manually between irrigation sets.

e. **Big Gun** - consists of a large sprinkler *(or sometimes a boom of sprinklers)* which is pulled continuously during irrigation. Water is supplied to the sprinkler*(s)* by a flexible hose.

f. **Overland Flow** - is a technique used on sloping land where water is delivered at the high end *(using gated pipes or pipes with holes)* and allowed to flow down the slope.

g. **Drip or Trickle Irrigation** - the frequent, slow application of water to individual plants or plant rows, through small diameter plastic tubing placed above or below ground.

Surface Hydrology - is the movement of water on the ground surface.

Topography - means a description of the local terrain eg. flat, rolling, rocky etc.

Wastewater - in the Guideline, wastewater means sewage that has been treated through either a lagoon system or sewage treatment plant and meets land or surface water discharge requirements.

APPENDIX IV

CHECKLIST - INITIAL DESIGN AND MONITORING

Check

1. Wastewater Quality _____
   - chemical analysis
     W.M. Ward Technical Services Laboratory
     Manitoba Environment
     745 Logan Avenue
     Winnipeg, Manitoba R3E 3L5
   - microbiological analysis _____
     Cadham Provincial Laboratory
     Manitoba Health Services Commission
     750 William Avenue
     Winnipeg, Manitoba R3C 3Y1

2. Land Base
   - property description and acreage _____
   - distance from source _____
   - accessibility _____
   - topography _____
   - buffer zone _____
   - agreements _____

3. Soils
   - soil analysis _____
     Soil Agrologist
     Manitoba Agriculture and/or Soil Survey

4. Crops
   - crop selected _____

5. Groundwater
   - groundwater appraisal: Manitoba Natural Resources _____

6. Cost Sharing _____

7. Irrigation System Selection _____

8. Additional Investigations

9. Irrigation System Design
   - pumping system _____
   - pipeline _____
   - irrigation system _____

10. System Operating Instructions _____

11. Health Considerations _____

12. Monitoring the System
    - soil tests yearly _____
    - wastewater sampling - chemical and microbiological analysis _____
    - water wells _____
    - optional - crop nutrient content _____
      - crop yield _____

13. Signs Posted _____